The Sidereal Messenger.

CONDUCTED BY WM. W. PAYNE,

Director of Carleton College Observatory.

FEBRUARY, 1887.

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Thou Lord in the beginning hast laid the foundation of the earth, and the heavens are the works of thy hands.

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MOTION OF THE LUNAR APSIDES.

E. COLBERT.*

The motion of the lunar orbit has long been a vexed question with the mathematicians. The following method of reconciling the theory with observation is novel, and perhaps will be accepted as conclusive:

It may be mentioned, incidentally, that the motion of the lunar apsides has for the last two hundred years been a stumbling block. NEWTON tried to account for it on the gravitation theory, but left it with the remark, "*Apsis lunæ est duplo velocior circiter*" (the motion is about twice as great as this). CLAIRAUT showed, in 1750, how to account theoretically for the other half, but the attempt to reduce the equations to a numerical form still left a residual, and when LAPLACE attacked the problem he was only able to make the theory responsible for 444 parts out of 445. It has been attempted to bridge over the difficulty by adding $2 \sin^2 \frac{1}{2}\gamma \,.\, d\Omega \div dt$ to the motion of the perihelion; which in the case of the moon is practically equal to $4 \sin^4 \frac{1}{2}\gamma$, because $d\Omega \div d☽ \;=\; \frac{1}{2}\sin^2 \gamma; \;=\; 2 \sin^2 \frac{1}{2}\gamma$, nearly. It will be observed that this quantity is not needed in that shape, neither is the existence of a second moon required to account for the perigeal motion. I may not be familiar with *all* the literature of the subject, but believe that the outstanding residual has not hitherto been eliminated by any investigator; and note a recent remark by G. W. HILL to the effect that it is not probable the perigeal motion will ever be accounted for by theory so closely as it can be obtained by a comparison of observations.

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If $1 - c$ represent the perigeal motion divided by that of the moon, then c^2 and $(1 - c^2)$ are the squares of two sides of the right-angled triangle the hypothenuse of which is unity; and $\sqrt{1-c^2}$ is the perturbation of the radius vector. (This is not new.)

The quantity $1 - c^2$ comprises a radial, which involves r^3: a tangential, depending on the square of the velocity in the orbit, involving r^4; and one that originates in the displacement, being really a perturbation of the perturbation. The last is usually treated as a single quantity, namely as a function of r^4. It is more philosophical to regard it as furnishing a multiple for each of the other two instead of being a quantity simply additive. Also, for obtaining the mean motion of the apsides, it is sufficient to derive the constant portion of each function considered, being what we shall here call the "Average Value" of the quantity:

With g the mean anomaly, e the eccentricity, r the radius vector, and a the semi-axis major, we have the following extension of a well-known equation:

$$
\begin{aligned}
\frac{r}{a} = 1 + \frac{e^2}{2} \\
&\left(-e + \frac{3}{8}e^3 - \frac{5}{3\cdot 8^2}e^5 + \frac{7}{18\cdot 8^3}e^7\right)\cos g \\
&\left(-\frac{3}{8}e^3 + \frac{5\cdot 3^2}{2\cdot 8^2}e^5 - \frac{7\cdot 3^4}{10\cdot 8^3}e^7\right)\cos 3g \\
&\left(-\frac{5^3}{6\cdot 8^2}e^5 + \frac{7\cdot 5^4}{18\cdot 8^3}e^7\right)\cos 5g \\
&\left(-\frac{7^5}{90\cdot 8^3}e^7\right)\cos 7g \\
&\left(-\frac{e^2}{2} + \frac{e^4}{3} - \frac{e^6}{16} + \frac{e^8}{180}\right)\cos 2g \\
&\left(-\frac{e^4}{3} + \frac{2}{5}e^6 - \frac{56}{315}e^8\right)\cos 4g \\
&\left(-\frac{27}{80}e^6 + \frac{81}{140}e^8\right)\cos 6g \\
&-\frac{128}{315}e^8 \cos 8g
\end{aligned}
$$

And an inversion of this series gives the following, which it is not necessary to carry out beyond the sixth power:

$$
\begin{aligned}
\frac{a}{r} = 1 &+ \left(+ e - \frac{e^3}{8} + \frac{e^5}{192}\right) \cos y \\
& \left(+ e^2 - \frac{e^4}{3} + \frac{3}{8} e^6\right) \cos 2y \\
& \left(+ \frac{9}{8} e^3 - \frac{81}{128} e^5\right) \cos 3y \\
& \left(+ \frac{4}{3} e^4 - \frac{16}{15} e^6\right) \cos 4y \\
&+ \frac{625\, e^5}{16 \cdot 24} \cos 5y \\
&+ \frac{203\, e^6}{120} \cos 6y
\end{aligned}
$$

Raising each of these expressions to the required powers, and omitting all that is periodical, we have as "average values":—

$$
\begin{array}{llllllll}
\text{For } \frac{r}{a} & : & 1 + \frac{e^2}{2} \\
\text{"} \ \frac{r^2}{a^2} & : & 1 + \frac{3}{2} e^2 \\
\text{"} \ \frac{r^3}{a^3} & : & 1 + 3 e^2 & + & \frac{3}{8} e^4 & + & \frac{1}{8^2} e^6, \text{ etc.} \\
\text{"} \ \frac{r^4}{a^4} & : & 1 + 5 e^2 & + & \frac{15}{8} e^4 & + & \frac{14}{9 \cdot 8^2} e^6, \text{ etc.} \\
\text{"} \ \frac{a}{r} & : & 1 \\
\text{"} \ \frac{a^2}{r^2} & : & 1 + \frac{e^2}{2} & + & \frac{3}{8} e^4 & + & \frac{15}{48} e^6 \\
\text{"} \ \frac{a^3}{r^3} & : & 1 + \frac{3}{2} e^2 & + & \frac{15}{8} e^4 & + & \frac{7}{4} e^6 \\
\text{"} \ \frac{a^4}{r^4} & : & 1 + 3 e^2 & + & \frac{45}{8} e^4 & + & \frac{35}{4} e^6
\end{array}
$$

For the solution of the problem we take the following as the most probable values of the quantities named. They are deduced from the figures given by NEWCOMB, in 1879, in his paper on the recurrence of solar eclipses. The epoch chosen is A.D. 1800. The processes of the subsequent computation are given, as they may be of use in verification; and all of the logarithms have been computed closely enough to secure accuracy in the last figure of the result as here presented. The mark '

following some of the numbers or logarithms indicates that the next succeeding figure would be nearly 5. The same mark inverted, thus, ‸ shows that the given value is too great by half a unit, or nearly so, in the right hand place:

		Logarithms.
☉'s daily motion,	3548″.1927904	3·55000 72091
Sidereal year, days,	365 ·2563647	2·56259 77924
☽'s synodical rev. days,	29 ·53058844	1·47027 21009'
Sidereal rev. days,	27 ·32166120	1·43650 71016
☽'s daily motion,	47434″.890233	4·67609 78999'
☽'s — ☉'s daily motion,	43886″.697443	4·64233 29006
☽'s π, daily motion,	400″.9187565	2·60305 63747
Half square ratio sidereal periods;		
	= (1 ÷ 357·447).	97·44678 86227
	358·447 ÷ 357·447	0·00121 32943
Nominal perturbation; $\frac{m}{2}$	= 0·00278 98145	97·44557 53284

Then for $e_{,}$, the eccentricity of the earth's orbit, with $e_{,}$ = 0·01679228, we have by a preceding formula:

$(a_{,} \div r_{,})^3$ =	1·00042 31202	0·00018 37199

and taking an approximate value for ☽'s e, with γ = about 5° 8′ 40″.6 we obtain E, the perturbation of the perigeal motion due to the earth's elliptical figure, as follows:

Constant of precession (JULIAN) = 54″.94625			1·73993 805
Obliquity, (1800) = 23° 27′ 54″.8		cos	9·96251 23'
	50″.40230		1·70245 04
Daily soli-lunar	0″.1379940		9·13986 02
☽'s $m \div a^3$ × ☉'s $a_{,}^3 \div m_{,}$			0·33673 10
☽'s $(a \div r)^3$	1·00453 806		0·00196 64
$1 - (3 \div 2) \sin^2 \gamma$			9·99473 02‸
	2·154902		0·33342 75
☉'s $(a_{,} \div r_{,})^3$	1·000423		
Sum of ☽ and ☉ =	3·155325		0·49904 41
(3 ÷ 2) seconds sidereal arc in solar day,			6·28988 37
(Solar days in sidereal year)^2		a. c.	94·87480 44
Obliquity of ecliptic,		cos	99·96251 23'
Daily soli-lunar precession,	0″.13799 40	a. c.	0·86013 98
	306·468		2·48638 44

Twice do $\times$ Moon's mass, =	7·51744	a. c.	99·12395 63
Lunar precession,	0''.09424 18		98·97424 36
E on perigee,	0''.01253 718		98·09819 99
= d ☽	(0·00000 02643 03)		93·42210 20
$2E \div (1 - c^2)$ =	1·00003 14038 5 =		0·00001 36383

Our value of E is slightly larger than the one given by LAPLACE. The precession here used is greater than that observed; the difference being due to a planetary perturbation which causes the equinox to move forward a little more than 17'' in a century. The number 306.468 is the earth's moment of inertia divided by the momentum of the ring of matter that forms our equatorial protuberance.

The value of e is, however, a direct function of the perturbation. We obtain it as follows:

$(1 - c^2) \div 6$		97·44799 80098
Syn. $\div$ sid. period of ☽		0·03376 49993'
= $(e^2 \div p^2)$		97·48176 30091'
Whence e =	0·05489 97758	98·73957 057
e^2 =	·00301 39854	97·47914 11416
p =	0·99698 60146	9·99868 90662

Then, for the averages on radius vector we have:

$(r \div a)^3$ =	1·00904 53630 5'	0·00391 06910 0'
$(r \div a)^4$ =	1·01508 69601 8	0·00650 44721 7

Also for the inclination we have:

$$\left.\begin{array}{ll} 8\,e^2 \div 3 & = 0{\cdot}00803729430 \\ 3\,e^4\,p \div 8 & = +\qquad 339627 \end{array}\right\};\quad \gamma = 5^\circ\,8'\,39''815 + 0''804$$

$\sin^2\gamma = 0{\cdot}00804\,069057$ 97·90529 335

When n is an even power, the average value of $\sin^n\gamma$ is

$$\frac{n\,(n-1)\,.\,(n-2)\,\ldots\,(\tfrac{1}{2}n+1)}{2^n\,(1\,.\,2\,.\,3\,.\,4\,\ldots\ldots\,\tfrac{1}{2}n)}$$

Giving $(1 \div 2)$ for $\sin^2$; $(3 \div 8)$ for $\sin^4$;
$(5 \div 16)$ for $\sin^6$; $(35 \div 128)$ for $\sin^8$; etc.

Cos^2 ☽'s latitude $= 1 - \sin^2\gamma\,\sin^2$ longitude. Hence we get the following values, not for the latitude at any particular point but the *average* cos, $\cos^2$, etc., of the ☽'s latitude:

$$\cos \text{ lat.} = 1 - \frac{1}{4}\sin^2\gamma - \frac{3}{64}\sin^4\gamma - \frac{5}{256}\sin^6\gamma - \frac{175}{16384}\sin^8\gamma.$$

$$\cos^2 \text{lat.} = 1 - \tfrac{1}{2}\sin^2\gamma.$$

$\cos^3 \text{lat.} = 1 - \frac{3}{4} \sin^2 \gamma + \frac{9}{64} \sin^4 \gamma + \frac{5}{256} \sin^6 \gamma + \frac{105}{16384} \sin^8 \gamma.$

$\cos^4 \text{lat.} = 1 - \sin^2 \gamma + \frac{3}{8} \sin^4 \gamma.$

These relations give us:

$\cos^3$ lat.	=	0·99397 85840 :	9·99737 70272
$\cos^4$ lat.	=	0·99198 35542 :	9·99650 44722

And these multiplied into the average values of r^3 and r^4 give the average third and fourth powers of the projection of r on the plane of the ecliptic:

It is important to note that the sum of the cube cosines for an inclination of $5° 8' 40''.619$ is equal to that for a medial value of $0''.804$ less; so that our computation gives us $5° 8' 39''.815 \pm 5''$. This corresponds precisely to the Hansenian value of $5° 8' 39''.96$ corrected by the $-0''.15$ by Newcomb deduced from a discussion of the Greenwich and Washington observations from 1862 to 1874.

If ξ be the ☽'s distance divided by that of ☉, and taking the parallaxes as equal to $3422''.75$ and $8''.794$, we have $\xi^2 = 0·000006601803$; and the value of $3m \div 2$ must be multiplied into $(1 + \frac{9}{8} \xi^2$, etc.) and $(1 + \frac{15}{8} \xi^2$, etc.) for the perturbative series in the direction of r and perpendicular thereto.

For the effect due to the "variation," let $1 + x$ and $1 - x$ represent the semi-axes of the ellipse, the longer axis being in quadratures and the other in the syzigies. Let w be the *mean* angular distance from the direction of the minor-axis of this ellipse. Then if $r_\circ$ denote the distance from the centre to any point in the circumference, we have, by comparison of the ellipse with its circumscribing circle:

$$r_\circ^2 = \sin^2 (w + dw) . (1 + x)^2 + \cos^2 (w + dw) . (1 - x)^2;$$
$$= 1 + x^2 - 2x \cos 2w + 4Q\, x^2 \sin 2w;$$

if Qx denote the maximum perturbation in longitude in the average orbit:—that which gives unequal areas in equal times.

Now, $1 + x^2 = a_\circ^2$, if $a_\circ$ be the radius of the circle of equal area that would have been described in the absence of compression; because $(1 + x) . (1 - x) = 1 - x^2$. Hence

$$r_\circ^2 = a_\circ^2 - 2x \cos 2w + 4Qx^2 \sin^2 2w,$$

if there were no change of area; and becomes

$$\left(1 + \frac{x^2}{3}\right) . (1 - 2x \cos 2w + 4Qx^2 \sin^2 2w)$$

on account of solar perturbation on $a_\circ$. From this we have:

$$r_\circ^3 = \left(1 + \frac{x^2}{2}\right) \cdot \left(1 + \frac{3}{4} x^2 + 3\,Qx^2 + \frac{9}{4} Q^2 x^4\right)$$

$$r_\circ^4 = \sqrt[3]{\left(1 + \frac{x^2}{2}\right)^4} \cdot \left(1 + 2x^2 + 4\,Qx^2 + 6\,Q^2 x^4\right).$$

The numerical values are as follows:

$3\,(t \div t_,)^2$		a. c.	1·77506 01269'
e^2			97·47914 11416
$(\text{syn} \div \text{sid})^2 - 1$	$= 0·16823\ 44223$		9·22591 48612
$= 4x \div (1 + x)^2$			98·48011 6130

which is the square of the average eccentricity in the hypothetical orbit described by the moon once in each synodical lunation.

x =	·00766 81608		97·88469 12105
$1 + x$			0·00331 75364
$1 - x$			9·99665 69260
x^2	·00005 88006 9		95·76938 24210
$(1 + x) \div (1 - x)$	$= \tan (45^\circ + 1581''.633)$	=	0·00666 06104
$1 + (x^2 \div 2)$			0·00001 27682
$(1 - e^2) \div 2$			97·92511 926
☽'s daily motion $\div\ p$ average $\cos^3 \gamma$			4·68003 181
	402''.857	=	2·60515 107
add	1581''.633		
	1984''.490		3·29764 88
	Syn ÷ sid ☽		0·03376 50
	2144''.934; = Variation;	=	3·33141 39
And Q =		(log)	9·40603 472'

Taking the logarithms, we have:

	For r^3		For r^4
Function of e	0·00391 06910		0·00650 32488
" γ	9·99737 70273		9·99650 44722
" x	0·00005 14323		0·00009 41089'
" ξ	0·00000 32255		53758
(logs.)	0·00134 23761		0·00310 72057'
and the numbers are		1·00309 57170	
		1·00718 02610	
		2·01027 59780	

The logarithm of the sum =		0·30325 56830'
$(3 \div 2)\, m$		97·92269 65831'
Solar; $(a_{,} \div r_{,})^3$,		0·00018 37199
Earth perturbation,		0·00001 36383
Planetary perturbation,		9·99999 96358
$1 - c^2$	·01683 25245 7	98·22614 92602
$1 - c$	·00845 19803 3	97·92695 84777
☽		4·67609 78999'
$(1 - c)$ =	400″.91875 926,	2·60305 63777,

(The planetary perturbation is that adopted by HILL in his tables of Venus. It is what LAPLACE terms the "indirect" perturbation; being that due to the enlargement of the earth's radius vector by planetary action, which lessens the solar disturbing force. The direct planetary perturbation is neglected, being infinitessimal as between the earth and moon.)

This result is identical with the value of the perigeal motion which NEWCOMB has obtained from a discussion of the eclipses of 2500 years preceding the present century. The difference between the two is less than one part in 100,000,000. Hence the problem is completely solved.

The following is the resulting value of the daily motion of g, the mean anomaly: 47033″.97147 4,

NEWCOMB, 47033″.97147

HANSEN; (Tables ☽), 47033″.97227

If any one should object to our deduction of the values of e and γ from that of the quantity sought he is respectfully referred to the top of page 174 of Loomis' Practical Astronomy, with the fact that a comparison of the rates of change in the values of the quantities shows this to be a parallel case with that given by LOOMIS on page 173. It is not necessary to our result to carry out the logarithm of e^2 to ten places; but I think there needs be no doubt in the future in regard to the precise values of e, γ, or x in the lunar orbit. Of course the numerical values of these quantities are slightly reduced since the beginning of the century by the decreasing eccentricity of the earth's orbit. There is still room for a possible very small correction to the assumed values of sidereal motion of the sun and moon.

CHICAGO, December 12, 1886.

ASTRONOMY AND THE ICE AGE.

W. H. S. MONCK, Dublin, Ireland.

For the Messenger.

It appears to me that the real difficulty in Dr. Croll's theory of the Ice Age has been but very partially met by that author and is altogether overlooked by Sir Robert Ball, the distinguished Astronomer Royal of Ireland, in the article which appears in the SIDEREAL MESSENGER for December, 1886. Briefly stated that difficulty is this: In the Glacial Period lands on which snow and ice now lie only in small quantities and for a comparatively short time were covered with a snow-cap or ice-cap to the depth of several hundred feet. It is plain that such a snow-cap could not be produced in one winter and melted off during the following summer. It must have gone on increasing in depth year after year for a considerable period during which the surface of the soil could never have been free from snow and ice. Now the difficulty is to show how this effect could be produced by an increased cold in winter *accompanied by a corresponding increase of heat during the ensuing summer.* It is admitted that the total amount of solar heat received by the earth in the course of the year at the period of greatest eccentricity is not less, but even greater, than that which it receives at any other period. Why then should not the summer-heat suffice to melt the winter snow and ice at all places where it is now capable of doing so? Indeed I do not see why this should not take place even if the extremes of heat instead of being 1.38 and 0.68, as in Sir Robert Ball's computation, were 2.00 and 0.00. As a matter of fact many places within the Arctic Circle are cut off for several days from all direct solar heat and yet they do not wear a perpetual snow-cap. Inequalities of temperature too appear, in some instances at least, to produce a tropical vegetation rather than a perpetual covering of snow. The mean temperature of Astrakhan is not higher than that of London but at the former place the finest grapes ripen in the open air and plants flower which in England are to be found only in greenhouses:

to which I may add that though the increase of solar heat at the period in question is small, (it has been estimated at $\frac{1}{300}$ of the total amount) the effect of exposure to this increased heat for centuries could hardly fail to be the reverse of that supposed by Dr. Croll. It would probably suffice to melt one foot of ice in three years, or 1,000 feet in 3,000 years, during which latter period there would be no perceptible change of eccentricity.

If we take a place at which the temperature remains steady throughout the year at the temperature of 31° F, it is plain that if not cut off from the sources of snow or rain it will wear a perpetual snow-cap. But suppose that I were allowed to divide the quantity of heat which this place receives in the year as unequally as I chose, could I not succeed in clearing away the snow for a time and perhaps even in bringing some kind of crops to perfection? Something of the kind in fact takes place in most localities where the range of temperature is very great.

The Glacial Period is, I think, still an unsolved mystery. It seems to have been preceded by a very long period of declining temperature as if the sun was being slowly cooled by radiation. This of course is in entire agreement with theoretic Astronomy. But how did the sun recover his heat at the close of the Glacial Epoch? This I suspect will be the ultimate form of the question, and if so, Astronomy alone can supply the answer.

RECENT STELLAR PHOTOGRAPHY.*

E. E. BARNARD.

Celestial photography began forty-six years ago; though as a means of accurate and delicate research its history is confined to the past three or four years.

As only late photographic work is to be considered at this time, we can only mention that done by the elder Draper, De

* Abstract of article in the *Daily American*, Nashville, Tenn., Jan. 2, 1887.

la Rue, Bond, Rutherford (whose photographs of the moon in 1864 are still perhaps the best made), Dr. B. A. Gould (photographs of star-groups and clusters in the southern skies), Professor Pickering (study of the light of stars) and Dr. Huggins (in attempting to photograph the corona without an eclipse).

Since the death of Dr. Henry Draper in 1882, celestial photography has received more attention in France and England than elsewhere. In France the refracting telescope is used altogether in photography, while in England preference is given to the reflecting telescope. These two instruments differ from each other chiefly in the way light rays are used as indicated by the meaning of the words refracting and reflecting. In the first, the lenses are specially corrected for the photographic or actinic rays ; in the second, no such correction is required, since the actinic and visual focuses coincide. A few years ago Mr. A. A. Common, of Ealing, England, procured a large reflecting telescope of thirty-six inches aperture. With this instrument he has closely pursued the work of celestial photography, and in 1883 he succeeded in making the finest photograph of that wonderful object, the Great Nebula of Orion, that has yet been made. This remarkable picture shows the nebula in all its singular ramifications. All the details that are seen in ordinary instruments are faithfully depicted, and many more that are beyond the reach of any but the most powerful instruments. But we must give the first honor to an American for obtaining the earliest accurate photograph of this magnificent nebula. This was made by Dr. Henry Draper, of New York. His photograph, made with an eighteen-inch reflector in 1882, created great interest at the time. It required an exposure of one hour and thirty-seven minutes and showed stars as faint as the fifteenth magnitude, which were scarcely visible to the eye in the same instrument. Mr. Common's picture is superior to Dr. Draper's. It shows much more detail, and the definition of the entire object is far better ; it brings out clearly the wonderful bat-like form of the Great Nebula.

Mr. Common is now having constructed a yet larger instru-

ment, the speculum of which will be five feet in diameter. The prosecution of photography with such an instrument will result in a still better knowledge of the far distant wonders of the sky.

But by far the most important work has been done at Paris. The skill and tireless energy of two brothers, the Messrs. Paul and Prosper Henry, have overcome, to a wonderful extent, the optical, mechanical and chemical difficulties that have been such a barrier to success in celestial photography. The instruments with which their remarkable success has been achieved, were constructed by themselves. Their first experiments were made with a telescope of nine inches aperture. The surprising results obtained with this led them to construct a larger instrument of 13.4 inches.

A few of the most important results cannot fail to be of popular interest, though it would require some familiarity with the subject to fully appreciate their wonderful pictures.

The Pleiades have been carefully studied, and accurate charts of the brighter stars made by such astronomers as Bessel, Wolf and Elkin.

Wolf's chart of the Pleiades, made at the Paris Observatory, required three years of assiduous work upon the part of a clever observer (1873, 1874, 1875) and also much work in 1878. Such a task may well be considered as the principal life work of an astronomer.

This chart contained 671 stars down to the thirteenth magnitude, and its author, after having thoroughly studied the entire group with the great telescope of forty-seven and one-fourth inches aperture, and also with the refractor of twelve inches, thought that he had attained the limit of the visible universe in that region of the sky. This same cluster was photographed at the same observatory in one hour's time. The old chart and the photograph were on the same scale, and could, therefore, easily be compared. The photograph showed in the same space 1,421 stars down to the sixteenth magnitude, or over twice as many as the eye had seen with a far greater instrument.

Doubts had already arisen as to the accuracy of some of the details of Wolf's chart, both in the position of the fainter stars and their magnitude. The photograph is perfectly accurate, and will stand as an authentic picture of the present appearance of the Pleiades. Beyond this extremely important fact the picture revealed many wonderful things that were unknown before. When the plate was developed, a small stain was seen close to, and apparently originating in, the star Maia, "very intense and effecting a very characteristic spiral form." Was it a stain? Another exposure showed the same object; this proved it to be real and to belong to the Pleiades; it must then be a new nebula, for no such object was known at that point. A close search for it with the great telescope of the observatory—five or six times as large as the one that photographed it—failed to show any trace of the object. A third photograph showed it as clearly as the previous two. Then the observers had the courage to announce the discovery. But though a diligent search was made for it with all the great telescopes of the world, only two—and these with difficulty—were able to see it. These were the great thirty-inch refractor at Pulkowa and the large telescope at Nice. Yet the Pulkowa telescope was five times as great as the one that photographed the nebula.

But this was not all the wonderful Paris photograph revealed. In 1859, Temple at Florence, Italy, discovered a large nebula about, and extending southwesterly for a half degree from, the star Merope of this group. Since that date observers have been equally divided as to its existence or non-existence; some seeing it readily, others not being able to even "glimpse it."

But that Paris photograph showed that it did exist, and not only that, instead of one there were four nebulæ at that point. But it must be admitted that the full extension of the nebula that is common to observers was not shown in the picture, the more diffused nebulosity seemingly having escaped the sensitive plate or lost in developing.

Among the discoveries in the Pleiades were a number of

minute companions close to several of the brighter stars. Some of these can be seen with no telescope, for the eye is dazzled by the light of the bright star. This in some part accounts for the difficulty in seeing the Maia nebula; the sensitive plate, however, is not so affected, being able to photograph a faint star close to a bright one as readily as if it were isolated on the dark sky. One of these little stars that had been carefully observed and measured by Wolf, the photograph showed to be two little stars close together.

Excellent photographs of the planet Saturn were obtained directly enlarged eleven times. The black separation of the two bright rings was clearly shown; the belts, the polar caps and the semi-transparent ring were also perfectly pictured.

Good photographs of Neptune were secured. The satellite of that planet was photographed in all parts of its orbit. This was all the more interesting, because photography is actually the only means of observing this satellite at Paris, the regular observing instrument not being powerful enough to deal with it. Photographs of double and multiple stars were obtained; also fine views of groups and clusters, including those of Hercules and Perseus.

The celebrated Ring Nebula, of Lyra, was photographed as a ring of light with a perfectly black center. A photograph of Epsilon Lyræ showed, after two hours exposure, stars fainter than the debilissima of Herschel, and of less than the sixteenth magnitude, while an exposure near Vega showed stars still fainter, some of which, it is believed, will never be revealed to mortal eye save through the aid of photography. When one of these pictures was being made, a small asteroid happened to be among the stars that were photographed, and as it was in motion it left its path on the sensitive plate as a trail of light.

In the meanwhile work has been pushed forward in England, and some of the very latest advances have been made there.

At the November meeting of the Royal Astronomical Society in London, Mr. Isaac Roberts exhibited negatives taken with his twenty-inch reflector which received the highest

praise. Some of these were parts of Cygnus, and covered the same ground that the Paris pictures showed. As the French and English negatives were on the same scale and covered identically the same regions, they were strictly comparable. It was found that Mr. Roberts' negatives showed on the average ninety-one stars to the square inch, while the Paris picture had only fifty-five stars in the same area.

Mr. Roberts also exhibited a negative of the Pleiades, which not only showed all the details photographed at Paris, but much more. This was made with an exposure of three hours, and showed that not only were the stars Alcyone, Maia, Electra and Merope surrounded by nebula, but that the nebulosity extends in streamers and in fleecy masses till it seems almost to fill up the spaces between the stars, and to go far beyond them. It suggests the probability that these principal stars of the Pleiades, together with many of the stars around them, are either directly involved or else in alignment with one vast nebula. This plate showed the Merope nebula in all its extension, just as it is seen and drawn by observers, which was not depicted in full upon the Paris photograph.

But all these results are not secured without the astro-photographer's brain being taxed. He cannot simply place his sensitive plate in the telescope and then sit down and leisurely wait till the propitious stars have kindly registered themselves. There must be a most delicate motive power applied to the telescope. So faint are some of the objects that the celestial photographer grapples with, that all the sensitiveness of his wonderful dry plates is brought into action, as we have seen, only after hours of exposure. Unless the telescope throughout this long interval is driven with unerring precision, the result is worthless. The most ingenious mechanism has been applied to the telescope, so that the great instrument follows the star slowly—almost imperceptibly, but surely.

The length of exposure varies with the brightness of the object. It has been calculated that with a thirteen-inch telescope the stars Vega and Sirius can be photographed in the $\frac{5}{1000}$ of a second; for a star just visible to the naked eye one-

half second, while for the faintest stars visible in the telescope, one hour and twenty minutes are required.

The image of one of these faint stars on the photographic plate is $\frac{1}{1000}$ of an inch in diameter. What does this signify? It signifies that for a period of eighty minutes the telescope must move in a direction contrary to the earth's rotation, with a velocity so uniform that the image of that stellar point must not vary from its original position on that plate by less than $\frac{1}{1000}$ of an inch, or the star would not be photographed at all.

So great has the importance of celestial photography become through the work of the Henry brothers that a congress of astronomers from all parts of the world will meet at Paris in April next to discuss plans for a grand survey of the sky. It is proposed to photograph the entire heavens from pole to pole, thus accumulating for our own use, and especially for that of coming generations of astronomers, the most accurate charts of the millions of stars, including those that are seen only in the largest telescopes. It is expected that the heavens will be divided up into zones and these distributed among different observatories, and thus the work can be rapidly pushed forward and completed in the next ten years.

The subjects that are proposed for discussion at this congress are various and thoroughly cover all the ground of celestial photography, among which are: The size and prices of the instruments; the method of pointing, whether with an additional telescope, as now, or by watching the image through the sensitive plate as it is being photographed; the size of the charts and the minimum limit of the stars they wish to secure; the best method to avoid confusion of accidental spots on the negative with small stars, the present method being to make three successive exposures on the same plate, which is shifted at each exposure, every star then is represented by a small triangle of three points, accidental spots being thus easily distinguishable. The best possible method of preserving the plates against deterioration by time will be one of the most important questions discussed. Several observatories have already ordered instruments from Paris, but these will not be

constructed until after the April meeting, as many improvements are expected to be brought forward then.

THE METEORITES, THE METEORS AND THE SHOOTING STARS.*

PROFESSOR H. A. NEWTON.

You are kindly giving to me an hour to-night in which I may speak to you. I do not have enough confidence in myself to justify me in speaking to such an audience as this upon one of those broad subjects that belong equally to all sections of the Association. The progress, the encouragements and the difficulties in each field are best known to the workers in the field, and I should do you little good by trying to sum up and recount them. Let me rather err then, if it all, by going to the opposite extreme.

Two years ago your distinguished President instructed and delighted us all by speaking of the Pending Problems of Astronomy, what they are and what hopes we have of solving them. To one subject in this one science, a subject so subordinate that he very properly gave it only brief notice, I ask your attention. I propose to state some propositions which we may believe to be probably true about the meteorites, the meteors, and the shooting stars.

In trying to interest you in this subject so remote from your ordinary studies I rely upon your sense of the unity of all science, and at the same time upon the strong hold which these weird bodies have ever had upon the imaginations of men. In ancient times temples were built over the meteorite images that fell down from Jupiter and divine worship was paid them, and in these later days a meteorite stone that fell last year in India became the object of daily anointings and other ceremonial worship. In the fearful imagery of the Apocalypse the terrors are deepened by there falling "from heaven a great star burning as a torch," and by the stars of heaven falling "unto the earth as a fig tree casteth her unripe figs when she is shaken of a great wind." The "great red dragon having seven

*An address by the retiring President before the American Association for the Advancement of Science, at Buffalo, August, 1886.

heads and ten horns and upon his heads seven diadems" is presented in the form of a huge fireball. "His tail draweth the third part of the stars of heaven, and did cast them to the earth." Records of these feared visitors under the name of flying dragons are found all through the pages of the monkish chroniclers of the Middle Ages. The Chinese appointed officers to record the passage of meteors and comets for they were thought to have somewhat to say to the weal or woe of rulers and people.

By gaining in these latter days a sure place in science, these bodies have lost their terrors, but so much of our knowledge about them is fragmentary, and there is still so much that is mysterious, that men have loved to speculate about their origin, their functions, and their relations to other bodies in the solar system. It has been easy, and quite common too, to make these bodies the cause of all kind of things for which other causes could not be found.

They came from the moon; they came from the earth's volcanoes; they came from the sun; they came from Jupiter and the other planets; they came from some destroyed planet; they came from comets; they came from the nebulous mass from which the solar system has grown; they came from the fixed stars; they came from the depths of space.

They supply the sun with his radiant energy; they give the moon her accelerated motion; they break in pieces heavenly bodies; they threw up the mountains on the moon; they made large gifts to our geologic strata; they cause the auroras; they give regular and irregular changes to our weather.

A comparative geology has been built up from the relations of the earth's rocks to the meteorites; a large list of new animal forms has been named from their concretions; and the possible introduction of life to our planet has been credited to them.

They are satellites of the earth; they travel in streams, and in groups, and in isolated orbits about the sun; they travel in groups and singly, through stellar spaces; it is they that reflect the zodiacal light; they constitute the tails of comets; the solar

corona is due to them; the long coronal rays are meteor streams seen edgewise.

Nearly all of these ideas have been urged by men deservedly of the highest repute for good, personal work in adding to human knowledge. In presence of this host of speculations, it will not, I hope, be a useless waste of your time to inquire what we may reasonably believe to be probably true. And if I shall have no new hypothesis to give to you, I offer as my excuse that nearly all possible ones have been already put forth. This Association exists, it is true, for the advancement of science, but science may be advanced by rejecting bad hypotheses as as well as by forming good ones.

I begin with a few propositions about which there is now practical unanimity among men of science. Such propositions need only be stated. The numbers that are to be given express quantities that are open to revision and moderate changes.

1. The luminous meteor tracks are in the upper part of the earth's atmosphere. Few meteors, if any, appear at a height greater than one hundred miles, and few are seen below a height of thirty miles from the earth's surface, except in rare cases, when stones and irons fall to the ground. All these meteor tracks are caused by bodies which come into the air from without.

2. The velocities of the meteors in the air are comparable with that of the earth in its orbit about the sun. It is not easy to determine the exact values of those velocities, yet they may be roughly stated as from fifty to two hundred and fifty times the velocity of sounds in the air, or of a connon ball.

3. It is a necessary consequence to these velocities that the meteors move about the sun and not about the earth as the controlling body.

4. There are four comets related to four periodic star-showers that have occurred on the dates April 20th, August 10th, November 14th and November 27th. The meteoroids which have given us any one of these star-showers constitute a group, each individual of which moves in a path which is like

that of the corresponding comet. The bodies are, however, now too far from one another to influence appreciably each other's motions.

5. The ordinary shooting stars in their appearance and phenomena do not differ essentially from the individuals in star-showers.

6. The meteorites of different falls differ from one another in their chemical composition, in their mineral forms and in their tenacity. Yet through all these differences they have peculiar common properties which distinguish them entirely from all terrestrial rocks.

7. The most delicate researches have failed to detect any trace of organic life in meteorites.

These propositions have practically universal acceptance among scientific men. We go on to consider others which have been received with hesitation, or in some cases have been denied.

With a very great degree of confidence we may believe that shooting stars are solid bodies. As we see them they are discrete bodies, separated even in prolific star-showers by large distances one from another. We see them penetrate the air many miles, that is, many hundred times their own diameters at the very least. They are sometimes seen to break in two. They are sometimes seen to glance in the air. There is good reason to believe that they glance before they become visible.

Now these are not the phenomena which may be reasonably expected from a mass of gas. In the first place, a spherical mass of matter at the earth's distance from the sun, under no constraint and having no expansive or cohesive power of its own, must exceed in density air at one-sixth of a millimeter pressure (a density often obtained in the ordinary air pumps) or else the sun by his unequal attraction for its parts will scatter it. Can we conceive that a small mass of gas, with no external constraint to resist its elastic force, can maintain so great a density?

But suppose that such a mass does exist, and that its largest and smallest dimensions are not greatly unequal; and suppose

further that it impinges upon the air with a planetary velocity; could we possibly have as the visible result a shooting star? When a solid meteorite comes into the air with a like velocity its surface is burned or melted away. Iron masses and many of the stones have had burned into them those wonderful pittings or cupules which are well imitated, as M. Daubrée has shown, by the erosion of the interior of steel cannon by the continuous use of powder under high pressure. They are imitated also by the action of dynamite upon masses of steel near which the dynamite explodes. Such tremendous resistance that mass of gas would have to meet. The first effect would be to flatten the mass for it is elastic; the next to scatter it for there is no cohesion. We ought to see a flash instead of a long burning streak of light. The mass that causes the shooting star can hardly be conceived of except as a solid body.

Again, we may reasonably believe that the bodies that cause the shooting stars, the large fireballs and the stone producing meteor, all belong to one class. They differ in kind of material, in density, in size. But from the faintest shooting star to the largest stone-meteor we pass by such small gradations that no clear dividing lines can separate them into classes.

See wherein they are alike.

1. Each appears as a ball of fire traversing the apparent heavens just as a single solid but glowing or burning mass would do.

2. Each is seen in the same part of the atmosphere, and moves through its upper portion. The stones come to the ground, it is true, but the brightly luminous portion of their paths generally ends high up in the air.

3. Each has a velocity which implies an orbit about the sun.

4. The members of each class have apparent motions which imply common relations to the horizon, to the ecliptic, and to the line of the earth's motion.

5. A cloudy train is sometimes left along the track both of the stone-meteor and of the shooting star.

6. They have like varieties of colors, though in the small me-

teors the colors are naturally less intense and are not so variously combined as in the large ones.

In short, if the bodies that produce the various kinds of fireballs had just the differences in size and material which we find in meteorites, all the differences in the appearances would be explained; while, on the other hand, a part of the likenesses that characterize the flights point to something common in the astronomical relations of the bodies that produce them.

This likeness of the several grades of luminous meteors has not been admitted by all scientific men. Especially it was not accepted by your late president, Professor J. Lawrence Smith, who by his studies added so much to our knowledge of the meteorites.

The only objection, however, so far as I know, that has been urged against the relationship of the meteorites and the star-shower meteors, and the only objection which I have been able to conceive that has apparent force, is the fact that no meteorites have been secured that are known to have come from the star-showers. This objection is plausible and has been urged both by mineralogists and astronomers as a perfect reply to the argument for a common nature to all the meteors.

But what is its real strength? There have been in the last one hundred years five or six star-showers of considerable intensity. The objection assumes that if the bodies then seen were like other meteors, we should have reason to expect that among so many hundreds of millions of individual flights, a large number of stones would have come to the ground and have been picked up.

Let us see how many such stones we ought to expect. A reasonable estimate of the total number of meteors in all of these five or six star-showers combined makes it about equal to the number of ordinary meteors which come into the air in six or eight months. Inasmuch as we can only guess at the numbers seen in some of the showers let us suppose that the total number for all the star-showers was equal to one year's supply of ordinary meteors. Now the average annual number of stone-meteors of known date, from which we have secured

specimens, has during this hundred years been about two and a half.

Let us assume then that the luminous meteors are all of like origin and astronomical nature ; and further assume that the proportion of large ones, and of those fitted to come entirely through the air without destruction, is the same among the star-shower meteors as among the other meteors. With these two assumptions a hundred years of experience would then lead us to expect two, or perhaps three, stone falls from which we secure specimens during all the half-dozen star-showers put together. To ask for more than two or three is to demand of star-shower meteors more than other meteors give us. The failure to get these two or three may have resulted from chance, or from some peculiarity in the nature of the rocks of Biela's and Tempel's comets. It is very slender ground upon which to rest a denial of the common nature of objects that are so similar in appearance and behavior as the large and small meteors.

It may be assumed then as reasonable that the shooting stars and stone-meteors, together with all the intermediate forms of fireballs, are like phenomena. What we know about the one may with due caution be used to teach facts about the other. From the mineral and physical nature of the different meteorites we may reason to the shooting stars, and from facts established about the shooting stars we may infer something about the origin and history of the meteorites. Thus it is reasonable to suppose that the shooting stars are made up of such matter and such varieties of matter as are found in meteorites. On the other hand, since star-showers are surely related to comets, it is reasonable to look for some relation of the meteorites to the astronomical bodies and systems of which the comets form a part.

This common nature of the stone-meteor and the shooting stars enables us to get some idea, indefinite, but yet of great value, about the masses of the shooting stars. Few meteoric stones weigh more than one hundred pounds. The most productive stone falls have furnished only a few hundred pounds

each, though the irons are larger. Allowing for fragments not found, and for portions scattered in the air, such meteors may be regarded as weighing a ton, or it may be several tons, on entering the air. The explosion of such a meteor is heard a hundred miles around shaking the air and the houses over the whole region like an earthquake. The size and brilliancy of the flame of the ordinary shooting star are so much less than that of the stone-meteor that it is reasonable to regard the ordinary meteoroid as weighing pounds or even ounces, rather than tons.

Determinations of mass have been made by measuring the light and computing the energy needed to produce the light. These are to be regarded as lower limits of size, because a large part of the energy of the meteors is changed into heat and motion of the air. The smaller meteors visible to the naked eye may be thought of without serious error as being of the size of gravel stones, allowing, however, not a little latitude to the meaning of the indefinite word gravel.

These facts about the masses of shooting stars have important consequences.

The meteors, in the first place, are not the fuel of the sun. We can measure and compute within certain limits of error the energy emitted by the sun. The meteoroids, large enough to give shooting stars visible to the naked eye, are scattered very irregularly through the space which the earth traverses, but in the mean each is distant two or three hundred miles from its near neighbors. If these meteoroids supply the sun's radiant energy a simple compuatation shows that the average shooting star ought to have a mass enormously greater than is obtained from the most prolific stone fall.

Moreover, if these meteoroids are the source of the solar heat their direct effect upon the earth's heat by their impact upon our atmosphere ought also to be very great: whereas the November star-showers in some of which a month's supply of meteoroids was received in a few hours do not appear to have been followed by noticeable increase of heat in the air.

[TO BE CONTINUED.]

TELESCOPIC ILLUMINATION.

ORMOND STONE.*

For the Messenger.

Miss Byrd, in her pleasing address on "Popular Fallacies about Observatories," says, "I raise no objection to poetry or velvet gowns, but until some one invents a way of lighting telescopic fields so that the observer is not obliged constantly to handle greasy lamps, the question is not open to discussion; the bans between poetry and practical astronomy are positively forbidden." And adds that "the modern observer is mindful of sulphuric acid and sperm oil and dons an old coat, or a shabby dress, as the case may be."

In electricity a means of illumination has been found which is practically all that could be desired. The reading circles of the great equatorial of the Leander McCormick Observatory have been illuminated by electricity from the beginning, although some difficulty was experienced at the very first in obtaining a battery which would do the work properly and with little care. Edison incandescent lamps of one-candle power are employed, run by a somewhat superior form of the ordinary bichromate battery, known as the Orne Motor Battery.

Since the time required to make a single reading of either circle is short, the intervening time is ample to allow the battery to recuperate and the illumination is practically constant. In making observations of double stars, however, this form of battery runs down so quickly as to be practically useless. After some experimenting it was found that a single candle-power lamp run by two Edco-batteries gave results in every way satisfactory. The Orne battery has small circular cups, while the Edco cells are large, each battery being supplied with two cells, each cell having a 6×8 inch carbon plate and two zinc plates of the same size.

When the Edco is first put in order, a single battery of two cells arranged for intensity is ample. After the electro-motive force has diminished, the "quantity" is increased by the addition of the other battery. The directions are that the porous

* Director of the Leander McCormick Observatory, University of Virginia.

cups be replenished each day; this, however, is not done in practice; in fact, no care is taken of the batteries further than to lift the plates out of the fluid when the night's work is done. At the end of a couple of months, a short time is spent in cleaning and replenishing the cells. When in use, the cover should never be allowed to rest on the cell, but should be separated from it. This can be done by laying a small pine strip between the cover and the cell. If the air is excluded there is danger of burning the plates.

The opening of a carboy of acid is so dangerous a process that if the acid be purchased in quantity it is better to do so through a neighboring druggist and let him open the carboy.

An old suit of clothes should be worn when cleaning the batteries or mixing the fluids. The cleaning of the batteries occurs, however, so seldom as to be really a very trifling matter. The Orne battery requires about the same care, but is fed by the refuse fluid from the Edco. Five or six Orne cells are usually employed, arranged for intensity.

The same battery is used for both reading circles, being turned on to either circle by a button switch conveniently located near the eye-end of the telescope tube. The Edco battery also runs two lamps, one being used at a time. The switch for these lamps is placed at the rear of the observing chair. One of the lamps is used for illuminating the micrometer wires, the other the observer can carry in his hand, and with it reads the position circle of the micrometer, and makes his record in his observing book; in short, uses it for any purpose he may desire.

A large cork is so cut that the lamp nestles in one end, and is thus protected from breaking. The wires run through, but are fastened to the cork, so that any pull on the wires does not produce a pull on the lamps themselves. This is important, as the connections to such small lamps are necessarily so delicate as to be easily broken. The cork fits into a tube at one end of the micrometer box, or may be used as a handle for carrying in the hand. These lamps are used all night without sensible diminution of intensity. Oil lamps are wholly

discarded, and the astronomer's work at night is as cleanly as his office work in the day.

In observing the Nebula of Orion, one of the lamps hangs by its wires from the eye-end of the telescope, at a convenient height for reading the observing book, the cork acting as a shade. The room is thus kept dark, except at the instant the record is being made, and even then the eye is shaded.

The unsteadiness of the ordinary lamps employed with the Zollner photometer is one of the principal objections to its use. No such objection could exist if illumination by electricity were employed.

The success of the experiment here has resulted in the use of electricity, at least for circle illumination, at West Point, Yale, and other observatories. At the Cape of Good Hope, as was afterwards learned, storage batteries had been previously employed, but it seems to me preferable to work from the battery directly. Of course, where steam or other power is at hand, as at Princeton, a dynamo is naturally employed.

THEMES IN FOREIGN ASTRONOMICAL JOURNALS.

Astronomische Gesellschaft. In the fourth part of this German publication for 1886 is found, among other valuable articles, a review by J. Luroth, of Professor Newcomb's article which was published in No. 4, Vol. VIII, of the *American Journal of Mathematics*, and entitled *A generalized theory of the combinations of observations so as to obtain the best results.*

The reviewer points out with care the differences between the theory suggested by Professor Newcomb and that commonly known as the method of Least Squares, and gives the principal mathematical expressions of the new theory, and completes the review in the following language:

"It is clear from the foregoing process, that good observations enter into the result with less weight, and the bad with greater weight, than is the case in the common theory, though one does not know at all whether an observation with a small error may not accidentally belong to a group of bad observations.

"Besides difficult computations which are necessarily performed by methods of approximation, it is a disadvantage to the foregoing theory that one knows neither the p [probability] nor the h [the modulus of precision] beforehand. Newcomb proposes, first of all, to seek the unknown quantity in the usual way, then to form the residuals for separate observations, and next by trial to ascertain what modulus of precision to employ and how many observations one must assign to each class in order that the actual distribution of the residuals may be nearly represented by the theory. What is arbitrary in this may not have any great influence on the result. On the other hand the result will not differ very much from that which the method of least squares gives, except in computation slightly, at least if one accepts (according to Bessel) that elementary errors have equal weights. But whether an empirical law of probability applied to residuals is an adequate expression of the probability of error, also in the case of different large elementary errors, may not be certain, at least, according to Bessel's researches without something further. As one can not come at once without assumption to a rule of computation for the combination of observations, so might the arbitrary acceptance of the theory of combinations with its simple deductions always fulfill the purpose in a most elegant manner to give a possible process for the discretion of the individual computer."

Ciel et Terre for December, 1886, contains a long article *On the staying of the sun during the battle of Muhlberg*, by C. Lagrange. His summary is as follows:

"1. The most recent account of a staying of the sun, that of the battle of Muhlberg, originated from an unusual state of the atmosphere and an extraordinary aspect of the sun. What eye-witnesses tell of this last is probable. No argument can be drawn from this recent tradition against the reality of the facts to which the more ancient traditions allude.

"2. The tradition of a staying of the sun is found among a great number of peoples far removed from one another.

"3. The account of the simultaneous staying of the sun and

the moon by Joshua ought for historic reasons to be regarded as concerning a real fact, which he places on the morning of the battle of Gideon and not the evening. That staying appears to be connected, in the narrative, with a retardation of the course of the sun. The durations are not fixed with precision.

"I have mentioned, in passing, the hypotheses compatible with the actual ideas of science which might serve to explain such a fact, in its immediate causes, either as a local phenomenon, or as a phenomenon embracing the whole surface of the earth."

Notice, in conclusion, a striking example of the reserve is to be imposed upon too absolute conclusions as to the facts which we refuse to admit because they go beyond the habitual order of our knowledge or common experience. We know that in the verses of the tenth chapter of Joshua that precede the account of the staying of the sun, there is mention of a shower of stones which destroyed in part the army of the Canaanitish kings. Voltaire, in his criticism of the Bible, treats as they merit (to him) that shower of stones and that staying of the sun. Less than fifty years afterwards the Academy of Sciences established the possibility of the fact reported in verse 11; how will it be with the fact mentioned in verses 12 and 13?

NOTE ON THE ORIGIN OF COMETS.

DANIEL KIRKWOOD.

Have comets originated in the solar system, or do they enter it from without? This question has been considered by Laplace, Proctor, H. A. Newton, and others. The last named presents arguments of no little weight in favor of their origin in inter-stellar space. To these arguments I shall attempt no reply. On the contraty, I have been disposed to accept them as, in the main, valid. For certain comets of short period, however, various facts seem to indicate an origin within the system.

(1.) According to M. Lehmann-Filhès the eccentricity of the third comet of 1884, before its last close approach to Jupiter, was only 0·2787.* This is exceeded by that of twelve known minor planets. Its period before this great perturbation was about 3619 days, and its mean distance 4·611. It was then an asteroid, too remote to be seen, even in perihelion. Its period was very nearly commensurable with that of Jupiter; six of the one being very nearly equal to five of the other. According to Hind and Krueger the great transformation of its orbit by Jupiter's influence occurred in May, 1875. Its present period is about 6½ years. It was discovered by M. Wolf at Heidelberg, September 17, 1884. Its history indicates an origin in the zone of asteroids.

(2.) *The second comet of 1867.*—This body was discovered by M. Tempel on the third of April. Its perihelion distance is 2·073; its aphelion 4·8973; so that its entire path, like those of the asteroids, is included between the orbits of Mars and Jupiter. The eccentricity of this comet at its successive returns has been as follows:

Date of Return.	Eccentricity.
1867	0·5092
1873	0·4625
1879	0·4624
1885	0·4051

The last is nearly identical with the eccentricity of Æthra, the 132d asteroid (0.38). The period, inclination, and longitude of the ascending node are approximately the same with those of Sylvia, the 87th minor planet.

This comet may be regarded as an asteroid whose elements have been considerably modified by perturbation.

Other comets furnish suggestive facts which bear upon the same question; but their discussion must await the development of additional data.—*Am. Journal of Sc. and Arts.*

R. R. Beard, Vice-President of National Bank, Pella, Ia., has a 6¼-inch Clark glass and is interesting himself in solar studies.

*Annuaire, 1886.

EDITORIAL NOTES.

Although not long, it is regretted that want of space makes it necessary to divide Professor Newton's very instructive address on meteorites, meteors and shooting stars.

The authorities of the Northwestern University at Evanston, Ill., have decided to build an astronomical observatory. The financial interest back of the enterprise is promising. Chicago must look out for its laurels.

Miss Mary E. Byrd's address at the laying of the corner stone of the new astronomical observatory of Carleton College, October 2, 1886, entitled, "Popular Fallacies about Observatories," has received general and very favorable notice at home and abroad. It was reprinted in full in the *Observatory*, and the following are the words of a Fellow of the Royal Astronomical Society, as taken from the *English Mechanic:*

"The mention of the *Observatory* suggests to me to recommend the perusal, in the current number of that serial, of a report of an address delivered at the laying of the corner stone of the new astronomical observatory at Carleton College, Northfield, U. S., by Miss Mary E. Byrd, the assistant in mathematics and astronomy. I would especially advise all those to read it who picture to themselves astronomers lying luxuriously on their backs, on handsomely upholstered sofas of the last degree of mechanical refinement and ingenuity, and gazing on lunar details, the wonders of the Saturnian system, or the clusters in Perseus, Cygnus and Lyra in a warm, comfortable and convenient apartment. A better or more truthful description of the mere 'grind' of ordinary observatory work it will be difficult to find anywhere."

U. S. Naval Observatory.—The report of the superintendent, Allan D. Brown, for the year ending June 30, 1886, has been received. In it we notice that the 26-inch refractor has been used in observing the faint satellites of the outer planets and difficult double stars, and that "observations of stellar

parallax have also been made." How Professor Hall made "observations of stellar parallax," we can not imagine. Of course he was successful, and therefore Supt. Brown ought to direct the great Washington equatorial at once to the observation of the solar parallax and speedily have done with that knotty little puzzle that has been in the way of everybody since the times of Tycho.

As usual, the reductions of the meridian circle observations are three years behind. The observatory has suffered for years in this way because it has not been supplied with a sufficient computing force to do the work. Without additional help, the proposed Transit Circle Catalogue, which is also greatly needed, will be a thing of the distant future.

In Professor Harkness' report of the work of the Transit-of-Venus Commission, made to the superintendent last October, it is stated that the computations for deducing the position angle and distance of Venus relatively to the sun's center, from the measures of the photographs of eleven different stations, had all been revised and checked. The work has since been advancing and is now near completion, if we are rightly informed.

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*Lalande 4219.**—R. A. $2h$ $10m$; Decl. $-18° 45'$ (1890); Magnitudes 8.0—8.8. This double star was observed here in 1886, and upon reduction was found to differ widely in P. A. from Prof. Hall's measures in 1879. Upon searching I could find no other observations until Prof. Hall kindly sent me some unpublished ones he had made in 1885. The measures are as follows:

Time.	P. A.	Δ	No. of Obs.	Observer.
1879.92	311.8	2.22	2	H.
1885.04	333.4	2.29	3	H.
1886.84	336.8	2.12	2	L.

So rapid a change in P. A. led to the suspicion that the motion was due to proper motion of the principal star. By request, Dr. Wilson collected the observations of position and

* Mr. Burnham tells me this star was discovered to be double by Dr. Hastings.

found that a proper motion of $-0.002s$ in α and $-0.24''$ in δ made the observations which extended over a period of about eighty years, agree pretty well.

Upon applying this motion to Prof. Hall's first observation in order to reduce it to the time of the other two, the P. A. was found to be 333° and the Δ $3.3''$. The difference in Δ $1.1''$ thus found is too great to be accounted for by errors of observation; so unless the companion has proper motion, or there is some considerable error in the value of the proper motion in δ, the motion must be binary in its nature.

A relative proper motion $\alpha - 0.008s$, $\delta - 0.08''$ will satisfy the measures approximately. F. P. LEAVENWORTH.

Leander McCormick Observatory, Dec. 28, 1886.

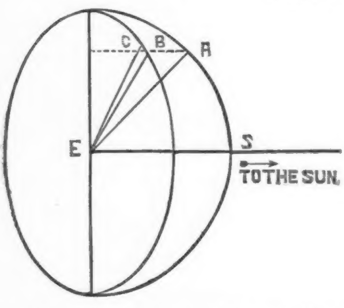
Yarnall's Catalogue.—We notice from the last report of the superintendent of the Naval Observatory, that Professor Frisby is charged with the duty of preparing a third edition of Yarnall's Catalogue. This revision will involve very considerable labor, and go forward mainly in the following manner: The lists of errors published from time to time by different astronomers have been carefully analyzed by reference to the annual volumes in which the observations are printed. If necessary, recourse is then had to the original record in the observing-books, extending over a period of more than thirty years; in some cases it has been necessary to refer to the chronograph sheets. If any errors are found the observations are reduced *de novo;* if no errors are found the stars are examined with the 9.6-inch equatorial and compared with those in well-known catalogues. Every catalogue in the library has been examined for names of stars noted as anonymous by Yarnall. Up to the present time a large number of errors have been discovered, many of which are, however, of but slight importance. It is hoped to have the revision completed during the next year (1887).

The Dearborn Observatory.—We learn from a circular issued by Professor E. Colbert, Jan. 8, that the Dearborn Observatory, which is the property of the Chicago Astronomical So-

ciety, is situated on ground leased to it by the now extinct University of Chicago. The Society is at present a mere tenant at will, and may be asked to vacate any time on sixty days' notice. It is, however, in receipt of an offer to transfer its telescopes, library and other property to an institution of learning outside of Chicago. To retain this noble observatory the city will need to act promptly. Some influential members of the Society are leading in appropriate endeavor to change its site in the city and remount its instruments. It would be the great and sad mistake of the greatest inland city of this continent to allow its chief scientific attraction to be banished in poverty.

Motion of the Lunar Apsides.—A few words explanatory and the accompanying figure may increase the student's interest in the leading article of this number.

MOON'S ORBIT.



If $AES = 45°$

$BEA = 1581''633$

$CEB = 402''857$

Sum, $CEA \times \frac{syn}{sid} = 2144''934$

Average "Variation" = $2144''934 . \sin 2w$,

EC being the true radius vector for mean angle AES.

In a private letter Mr. Colbert says:

"The fact that the lunar orbit is compressed in the direction of the line joining the earth and sun, instead of the contrary, has been noted by several of the men who compile text-books on astronomy, but I do not know of one that helps the reader to a precise comprehension of this very interesting phenomenon of motion under the influence of attraction—doubly interesting because it is paradoxical in the ordinary sense of the word, and apparently so in the proper acceptation of the term. Doubtless you have noticed that the 2145″ (nearly) given on

page 55 is the co-efficient of a perturbation in longitude, but is derived from that of the radius vector. The latter corresponds to a value of $26.25''$ cos 2 w. For + values of cos w it is less, and for — values greater, by a little less than $1''$ cos w. Those who may wish to compare these results with those used by Hansen in his tables for longitude and table XVI for parallax, or the modified values given by Newcomb, will do well to note that their $g-g'+(w-w')$ is the same quantity that I have denoted by w; being the mean longitude of the moon minus that of the sun."

In this connection we call attention to a misprint on page 55, line eighteen, $\cos^3 \gamma$ should be $\cos^3$ lat. The quantity referred to is that given in line four of page 54, used with the semi-parameter as a divisor.

The Smithsonian review of astronomy for 1886 is to be prepared by Mr. W. C. Winlock of the Naval Observatory, Washington, Professor Holden being unable to continue the review on account of pressing official duties. Mr. Winlock would be glad to obtain from amateur astronomers a brief account of any work undertaken or completed during the year,—with a description of observatories and instruments—for insertion in the report.

Dr. Swift's Fifth Catalogue of New Nebulæ.—Several of the nebulæ in "Catalogue No. 5 of Nebulæ discovered at the Warner Observatory," *Astronomische Nachrichten, No. 2763*, have previously been published in other places. A list of these is given below; the first column contains the number as given in the *Nachrichten*, the third column the previous place of publication, and the fifth column the name of the discoverer. Only as much of the description is given as appears interesting for comparison. Herschel's abbreviations are used; in the descriptions of nebulæ discovered at this observatory numerical magnitudes are used to indicate brightness, a nebula of about the sixteenth magnitude being the faintest visible with the 66 in. refractor; in these descriptions also the sizes are given in minutes of arc. In some cases the identity is doubt-

ful either on account of lack of agreement between the places or the descriptions; in these cases, however, had two nebulæ existed some note would probably have been made of the fact. In the case of No. 57 although the descriptions do not agree an unpublished sketch shows the equilateral triangle mentioned in the description. The description and place of the nebula near No. 54 has not been published previous to this.

1	pB	G. C. 5092	vF	Secchi.
13	eF pL	A. N. 2502, No. 14	eeF, vS, r	Stephan.
18	a, $1h\ 53.1m$; δ, $-0° 2.8'$	A. N. 2746, No. 208	a, $1h\ 52.8m$, δ, $-0° 1.4'$, No. 18?	Swift.
21	eeeF, pL	A. J. 146, No. 49	15.5 eS	Stone.
28	a, $2h\ 20.3m$, δ, $-0° 51.1'$	G. C. 5236: A. N. 2212, No. 9	a, $2h\ 20.2m$; δ, $-0° 53.9'$, No. 28?	Tempel.
30	eeF, pS	G. C. 5262	eeF	Stephan.
31	eeeF, vS	G. C. 5263	fainter than G. C. 5262, vS	Stephan.
33	eeeF, eee diff	A. J. 146, No. 61	15.0, neb?	Stone.
49	F, iR, 1st of 2	A. J. 146, No. 94	14.0, E 60°, stell N, 1st of 3	Stone.
		A. J. 146, No. 95	15.5, dif, 2nd of 3	Stone.
50	eF, vS, 2nd of 2	A. J. 146, No. 96	14.5, stell, 3rd of 3	Stone.
54	vF	Royal Ast. Soc. Vol. 44	not vF	Burnham.
		McCormick Obs.	15.0, 0.4′, P. A. 70°, Δ 2.4′ with No. 54	Muller.
56	eF, pS, R	A. J. 146, No. 113 A. J. 146, No. 114	16.0, 0.8,′ stell N 16.0, 0.8, stell N } P. A. 310°, Δ 0.4′, No. 56?	[Stone.
57	R, equilateral triangle 2st	A. J. 146, No. 116	pE 45°,	Leavenworth.
59	vF	A. J. 146, No. 122	14.0	Stone.
66	F, pS, eE	A. J. 146, No. 141 A. J. 146, No. 142	12.0, vS, spMN 12.0, vS } P. A. 110°, Δ 10″	Leavenw'th.

Leander McCormick Observatory, Jan. 12, 1887.

FRANK MULLER.

The Swift-Watson Intra-Mercurial Observations.—I have been much interested in the perusal of Professor Young's able paper in the MESSENGER for January, but think it a duty to record my dissent from his conclusion that the two objects seen by Swift, during the solar eclipse of July, 1878, were "certainly not the two seen by Watson." I do not wish to be understood as considering "the observation important" or otherwise; but think it is about time that the matter were set right. I presume it will be remembered that I was the chief of the party of which Swift was a member on the occasion referred to, and therefore ought to be able to speak with some authority in regard to it.

The fact is that Swift had no appliances to his telescope for measuring position or angular distance ; and made the unfortunate mistake of trying to locate the objects which he saw (or believed he saw) with a precision not warranted by the circumstances of the case. He was all right at the time of the eclipse, but did wrong in trying to make his observation agree with that of Watson. His first idea was that he saw a fixed star, and an intra-mercurial planet near it. On a star chart which I had prepared previous to the eclipse he marked down the position of the supposed stranger as being near a small star that was much farther away from the sun than was *Theta Cancri*. Only after I had called his attention to the fact that the star selected by him could not possibly have been seen through his telescope at the time, and that it must have been *Theta*, if any, that was seen near his intra-mercurial planet, did he arrive at the conclusion that *Theta* was probably one of the objects seen by him. His subsequent statements of position, and efforts to make his observation agree with that of Watson, were, as I think, unwarrantable.

I can, and do hereby testify, that Swift announced his supposed discovery before the news of Watson's observations reached me. I can also testify that no importance ought to be attached to his statements of position, beyond the fact that his objects were some distance to the right and below the place of the sun. Professor Hough, who was also a member of the party, endorses this statement of the case. I may add that I laid the facts of the matter before Watson the following winter, and discussed it with him at some length verbally. I have reason to believe that Watson would have made a full statement of the case in print but for his untimely death.

Permit me to add that I think Young ought to have mentioned Hough's work in his notice of Jupiter. E. COLBERT.

New Variable in Orion.—Gore's new star in Orion passed its maximum about Dec. 8. It appears to be diminishing in brightness more slowly than last year.

New York, Jan. 13, 1887. HENRY M. PARKHURST.

Lick Observatory.—A late California paper states that President Holden has contracted with Fauth & Company, Washington, D. C., for a micrometer for the 36-inch equatorial, and with Brashear & Company, Pittsburgh, Pa., for a spectroscope which shall be the most powerful yet made; both instruments to be completed by June 1. The great lenses are now in the observatory at Mt. Hamilton, and Warner & Swasey, Cleveland, Ohio, have work on the mounting of the telescope well under way, and it is expected that the transfer of the observatory, its instruments and funds, from the Lick trustees so-called, to the University of California, will take place in July next. The bequest of $700,000, made eleven years ago, has been expended in equipping the observatory so far, except $190,000 which is to be set apart for current expenses. It is thought that this amount will yield an annual income of $10,000 for this purpose.

President Holden is reported to say that the observing force, at first, will consist of two astronomers besides himself. The persons that he will nominate to the Board of Regents are S. W. Burnham of Chicago, and J. E. Keeler, formerly of Allegheny Observatory and now at Mt. Hamilton. The choice of Mr. Burnham is eminently wise. His work with the micrometer is unsurpassed and duly recognized everywhere. The revision of his double star catalogue will soon be possible if this programme is carried out. Mr. Keeler is a graduate of Johns Hopkins and Berlin Universities, and for some time past has been assistant to Professor Langley. He is already a specialist of reputation in astronomical physics and is devoting himself to the spectroscope. We notice also that President Holden has been invited by the Minister of France, resident at Washington, to be present in Paris, April 16, 1887, to attend a convention of leading astronomers of the world to discuss the best methods of using photography in astronomical work.

Brooks' Comet No. 3, of 1886, (discovered May 22, 1886,) proves to be an interesting object, moving in an elliptical orbit of short period. Soon after discovery Dr. Oppenheim of

Berlin computed its elements and gave it a period of about nine years. Now Hind, on more complete data, finds that it is moving in an elliptical orbit, with the short period of six years and three months.

Lick Telescope Object-Glass.—As eleswhere stated, the lenses for the great equatorial of the Lick Observatory have been shipped from Cambribgeport, Mass. by express to San Jose, California; thence they were taken to the Observatory building on Mt. Hamilton. The manner in which they were cased at the shops of the Clarks in Cambridgeport for this long journey may interest some of our readers.

They were wrapped separately in fifteen or twenty thicknesses of soft, clean, cotton cloth. Next came a thick layer of cotton and then a layer of paper. The glasses were then put into boxes of wood and lined with felt. No nails were used near the glasses, and the boxes were made the shape of the glasses. The boxes were inclosed in two others of steel, each about the shape of a cube, being packed tightly with curled hair. Each steel box was inclosed in another steel box, the inner sides of which were covered with spiral springs. Both steel boxes were made air tight and water proof, and the outer chests packed with asbestos to render them fire-proof. Each was then suspended by pivots in strong wooden frames, with contrivances for turning each chest one quarter around every day during the journey to California. This is to prevent any molecular disarrangement in the glasses and to avoid the danger of polarization, it being feared that the jarring of the train would disturb the present arrangements of the molecules unless the position of the glass should be changed and all lines of disturbance thus broken up.

C. H. Rockwell's Almucantar sustains its good record in latitude work admirably. Recently he says: "For July 24, I had eight pairs of stars. Five of these gave a correction of less than one-tenth of a second to my assumed latitude, 41° 04′ 13.72″. The other three pairs gave corrections less than two-tenths of a second. The largest was 0.192″; the smallest, 0.001″.

Sun Spots.—From my observing book I make the annexed showing of sun spots for 1886, which may interest some of the readers of the SIDEREAL MESSENGER.

1886.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Spots..........	15	16	22	24	19	19	23	24	24	20	1	6
No Spots......	2	1	0	1	3	3	4	4	4	3	22	5
Cloudy, no Observ'n ..	14	11	9	5	9	8	4	3	2	8	7	9

From the 30th of October to the 16th of November the sun was more free from spots for a longer continuous period than has occurred since 1879. G. G.

THE PLANETS.

Mercury will be near the sun Feb. 1, and far to the south.

Venus is an evening planet and Feb 1 sets *6h 16m.*

Mars is near the sun and in the remote part of his orbit, and consequently of little interest to observers at present.

Jupiter rises Feb. 1, 14 minutes after midnight, and is in conjunction with the moon Feb. 13 at 7 o'clock A. M.

Saturn is an evening planet and rises at *2h 51m* P. M. on the 5th day of the month. It is more than 22° north declination.

Uranus rises at 10 o'clock and 14 minutes in the evening Feb. 1.

Neptune rises 21 minutes before midnight on same date before mentioned. The above figures give the approximate places for the purpose of identifying objects only.

Ten Years' Progress in Astronomy.—Professor Young notices some errors in his paper in our last issue. On page 35, date of photography at Cambridge, by slip of pen, was written 1861; it should have been 1851. The others following he justly charges to our proof-reader. Absence of the editor during part of the printing, is the explanation. He says:

"Let me congratulate you on *improved* proof-reading. But you are not perfect yet. I notice,

"On page 31, about middle of page, 'acceleratio*u*.'

"On page 37, about middle of page, Dober*e*ck for Doberck.

"On page 39, near top, Crossly for Crossley.

"On page 44, near bottom, Mich*a*elson for Michelson (twice).

"On page 47, near top, 'geogra*g*hical.'

"On page 47, near middle, 'Iraunhofers'!

"On page 48, two-thirds down, Exe*c*ter for Exeter."